

Water Chemistry and Atlantic Salmon Physiology

Anadromous Atlantic salmon have a complex life history, inhabiting and migrating throughout freshwater streams and rivers, brackish estuaries, coastal waters, and the North Atlantic Ocean. Juveniles typically reside in freshwater for two years before migrating into marine environments. To make this transition, parr undergo a physiological transformation (*smoltification*) and enter the smolt life history stage.



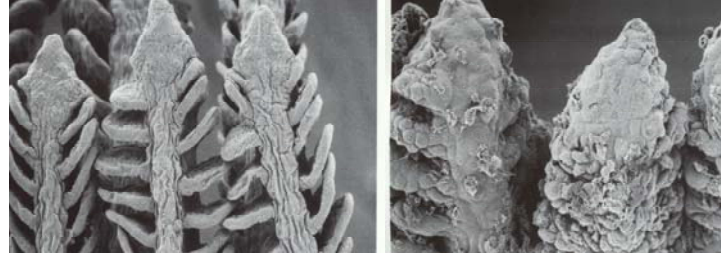
An Atlantic salmon smolt. Dramatic physiological changes must take place before smolts develop a tolerance for salinity and are able to transition into estuarine and marine environments.

Water chemistry conditions that are not normally regarded as toxic to other life stages may be toxic to smolts. Because of the dramatic physiological changes that must take place before smolts can transition from freshwater into saltwater, they are especially sensitive to acidification (the process whereby acid deposition lowers the pH of surface waters). This is true even in rivers that are not chronically acidic and not normally considered as being in danger of acidification.

In Eastern Maine, landscape features cause rivers to be naturally acidic and especially prone to more intense episodic acidification. For example, spring flood events from snowmelt and heavy rains can further decrease already low pH. These low pH's can then increase the concentration of aluminum leached into the water. Soluble inorganic forms of aluminum are one of the principle toxicants suspected to affect fish health in acidified waters.

Aluminum is often bound by organic matter in this region, making it unavailable for gill absorption and therefore non-toxic to fish. In some instances, not all of the aluminum is organically bound, and under especially low pH conditions, aluminum can become extremely toxic to anadromous fish.

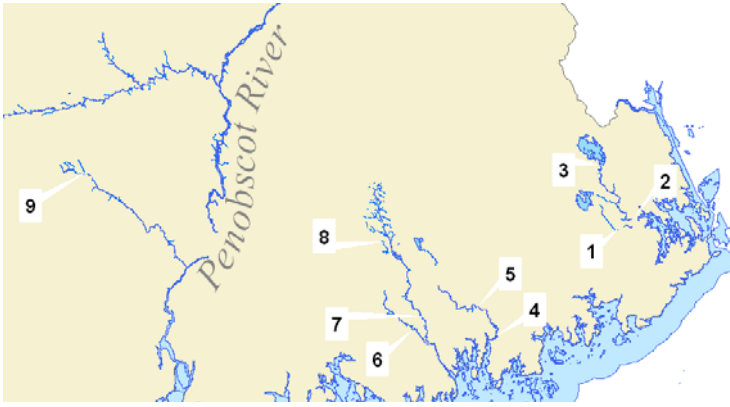
Laboratory studies have demonstrated that short-term exposure to acidic conditions and elevated levels of aluminum can block the normal development of salinity tolerance during smoltification. These sub-lethal episodes of low freshwater pH, when combined with increased aluminum, may increase the likelihood of mortality upon entry into saltwater.



In addition to absorbing oxygen and removing carbon dioxide, gills also regulate the exchange of ions. On the left, normal Atlantic salmon gill filaments. On the right, gill filaments damaged by aluminum.

In 2003, an interagency and stakeholder committee was organized to determine if river liming would be an appropriate and logistically feasible means by which to buffer against anthropogenic acidification. Prior to implementing a river liming program, however, an important step was to determine the mechanisms and efficacy of aluminum and pH interactions on juvenile Atlantic salmon under dynamic river conditions. To gather this baseline information, fisheries researchers set up a streamside rearing study.

The Streamside Rearing Study



Study Sites and Years Operational

- 1 Cathance Stream: 2004, 2005
- 2 Dennys R. (Clubhouse): 2004, 2005
- 3 Dennys R. (Meddybemps): 2004
- 4 Pleasant R. (Columbia Falls): 2004 - 2006
- 5 Pleasant R. (Saco Falls): 2004 - 2006
- 6 W.B. Narraguagus R. (Spragues Falls): 2005 - 2006
- 7 Narraguagus R. (Little Falls): 2006
- 8 East Bear Brook: 2006
- 9 Kenduskeag Stream: 2004

The streamside rearing study investigated the effects of episodic acid/aluminum fluxes on two juvenile life stages of Atlantic salmon. During the spring migration period, Atlantic salmon smolts and fry were held adjacent to the study rivers in rearing tanks supplied with ambient river water.

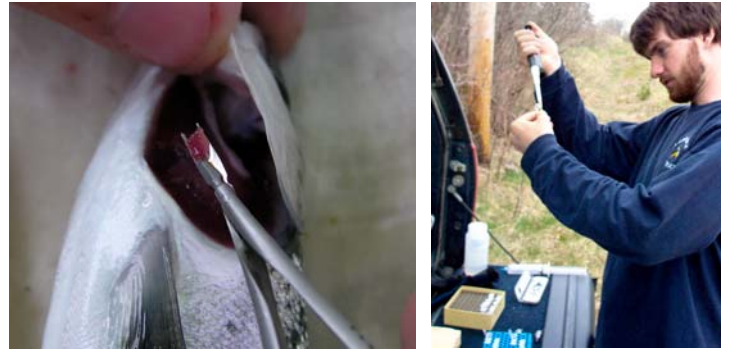


The 65 gallon streamside rearing tanks through which fresh water from the study rivers continuously flowed. These tanks were used to hold smolt and fry during the studies

In addition to the streamside rearing portion of the study, fish at the Dennys River site were held in water that had been passed through a limestone reactor (limestone increases the capacity of aquatic ecosystems to buffer against acidity). This was to simulate river liming and assess its potential utility as a mitigation tool.

In 2005, a portion of the smolts from the West Branch Narraguagus, Pleasant, and Dennys River were given a 72 hour seawater challenge, and in 2006, fish from each site were given a 30 day seawater challenge. The objective of the seawater challenges was to observe both seawater growth and survival as well as examine the potential sub-lethal effects of ambient river conditions on smolt physiology.

After three and six day exposures to ambient river water, limed water, and following the saltwater challenges, NEST researchers collected gill and blood samples from smolts. These samples were used to assess their physiological response to various environmental conditions.



Graduate student Trent Liebich takes a gill sample (top) and a blood sample (bottom) from an Atlantic salmon smolt. These samples help researchers understand a smolt's physiological response to stress (indicated by blood glucose levels) and ability to osmoregulate (indicated by gill ATPase and blood plasma chloride levels).

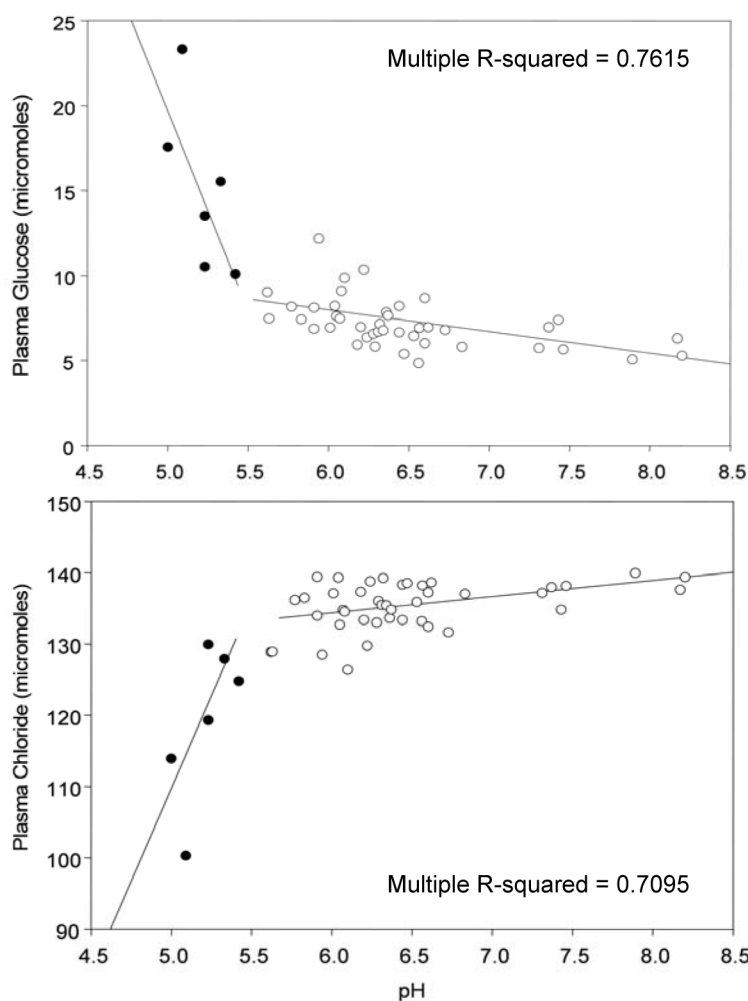
Preliminary results show a strong correlation between pH, plasma chloride and plasma glucose levels. This indicates that strong episodic acidification events may compromise the health and possibly even survival of wild Atlantic salmon smolts in Maine, especially in the Pleasant River, West Branch Narraguagus, and possibly some smaller tributaries where low pH has been observed. Smolts held streamside in locations with pH below ~5.6 appeared to exhibit elevated levels of stress (indicated by blood plasma glucose levels) and abnormal osmoregulatory functioning (indicated by the loss of plasma ions).

Although significant rain events that occurred during the streamside study were often associated with low pH, this was not always the case. On the Dennys River, impacts were not severe enough to see measurable differences in smolt physiology between treatment groups. Furthermore, during the 2005 and 2006 seawater challenges, all smolts that were exposed to saltwater survived. Preliminary data suggest that even when smolts may be impaired by the interaction of pH and aluminum, they may actually be able to recover in saltwater. However, the measurements used do not take into account potential sub-lethal impacts that may affect behaviors such as migration and predator avoidance.

Based solely on the preliminary results of the streamside rearing study, current water chemistry conditions do not appear to pose a significant threat to the Gulf of Maine distinct population segment of Atlantic salmon. However, water chemistry does have the potential to impede fish in certain watersheds.

Furthermore, the translation of physiological indicators of stress and osmoregulatory function into sublethal effects was untested and thus remains unknown. This study did not assess the effect of long term (greater than six days) or repeated exposures of smolts or fry to episodic low pH or high aluminum events. Nor did it assess the exposure of other life history stages (e.g. eggs and parr) to these events.

Researchers are continually expanding their understanding of water chemistry and its affect on aquatic ecosystems. Suitable water chemistry is critical to the health and survival of Atlantic salmon during the freshwater portion of their life history. As such, Maine's residents must still be mindful of how their actions could influence the integrity of the water resources around them.



A strong correlation between pH and blood plasma glucose levels (left) and plasma chloride levels (right). Plasma glucose levels provide an indication of stress, while plasma chloride levels provide an indication of osmoregulatory functioning. These graphs illustrate that beyond a low pH threshold, a smolt will become stressed and its osmoregulatory functioning affected.

The Northeast Salmon Team (NEST) operates within the Northeast Region of NOAA Fisheries Service to promote the recovery and future sustainability of Atlantic salmon.

We are composed of fisheries managers and scientists jointly based out of the Orono, Maine Field Station; scientists based out of the Woods Hole, Massachusetts Northeast Fisheries Science Center (NEFSC) and Narragansett, Rhode Island Laboratory; and managers based out of the Gloucester, Massachusetts Northeast Regional Office (NERO).

Please visit our website at <http://www.nefsc.noaa.gov/salmon/>

